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Art. XII.—*The Petrology of the You Yangs Granite.—A Study of Contamination.*

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Summary.

The You Yangs hills are a stock of giant granite rising above the plains about 30 miles south-west of Melbourne. The granite has intruded rocks of Lower Palaeozoic age. Assimilation of these rocks has contaminated the invading magma with sphene, ferromagnesian minerals, and numerous partially digested xenoliths of both sedimentary and igneous origin. In certain localities, drawing out of the xenoliths has led to local striping in the granite, and orthite, a mineral hitherto unrecorded from the granites of Victoria, occurs associated with the xenoliths. Sedimentary rocks which were shales and sandstones have given rise

to biotite- and quartz-rich xenoliths, whilst the igneous rocks, presumably Cambrian diabases and epidiorites, have given rise to horn blende- and diopside-rich xenoliths. All degrees of granitization are represented in the xenoliths.

As a result of this extensive contamination, the You Yangs granite is much more basic than the granite of neighbouring outcrops.

The granite has been invaded by dyke intrusions of two distinct periods. Two porphyry dykes, aplite, pegmatite, and quartz veins were associated with the late phases of the intrusion of the granite. One of the porphyry dykes (D.1. on the map), shows local variations due to the assimilation of granite and xenoliths. The second period of dyke activity occurred in the Tertiary, when two monchiquite dykes and a small plug were intruded, one of these dykes being nepheline bearing.

The trend of the more prominently developed joints in the granite is W. 20° N. and N. 30° E.

Location and Previous Work.

The You Yangs hills are situated about 30 miles south-west of Melbourne, in the parish of Wurdi Youang, county Grant. They form a series of rugged granitic ridges rising abruptly to 1,154 feet above sea level from the surrounding plains of Newer Basalt and Alluvium, which average about 150 feet above sea level.

Smaller areas of granite outcrop a few miles to the north-west, west, and south-west (see Fig. 1). These include the Dog Rocks, near Geelong, and the following occurrences, named after the parishes in which they occur, the Yowang outcrop, the Darriwil outcrop, the Anakie outcrop, and the South Anakie outcrop, which is not marked on the quarter sheets, and consists of a small exposure, south of the Tertiary volcanic hills of the Anakies.

The general geological relationships of the You Yangs area are indicated on quarter sheets Nos. 19 and 20 of the *Geological Survey Maps of Victoria,* published in 1863.

In 1907, Professor Skeats described the geology and physiography of the You Yangs (30), and, in 1919, a geological map of the area on a scale of 1 mile to 1 inch was prepared in the Geology Department, University of Melbourne. In 1932, a dyke rock was mapped by Coulson (5), who also recorded the occurrence of diabase rocks.

Local names added to the sketch map accompanying this paper were kindly supplied by Mr. Richmond, a local resident. The higher elevations of the ridges have been labelled P.1 to P.12, for purposes of relatively accurate location.

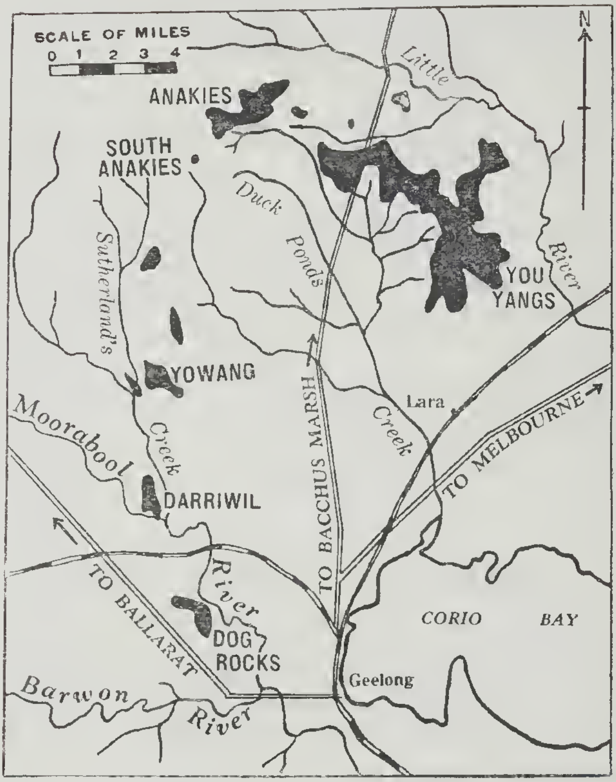

Fig. 1.—General map showing outcrops (in black) referred to in the paper.

The You Yangs Giant Granite.

Nature of the Intrusion.

The granite at the You Yangs is a single intrusion, relatively uniform in appearance, and shows no evidence of rapid chilling at the contact, or of a border phase.

The intruded sediments strike a little to the west of north, agreeing with the general strike of the Ordovician rocks of Victoria (30). Abundant xenoliths occur throughout the granite, so that apparently the magma advanced to its present position without any distortion of the country rock by a process of overhead "piecemeal" stoping (7).

Since large porphyritic felspars in the giant granite show only local planar parallelism, and the xenoliths are arranged in a haphazard manner, there has been no appreciable amount of magma streaming under directional forces.

Field Occurrences.

The area of granite exposed is about 12 to 15 square miles. The granite of the You Yangs is a typical mesocratic giant granite (4), the visible dark minerals consisting of individual crystals or clots of biotite and hornblende, which become locally concentrated in the neighbourhood of some of the xenoliths. Sometimes, bands of ferromagnesian minerals give rise to striping in the granite. This has been observed in two weathered out blocks of granite half way up the eastern slopes of P.2, in several quarried out blocks at the sides of the track near the Shelter Shed, and in Quarry 1 at the foot of the northern slopes of P.6. The major development is at Quarry 1, where the bands are puckered (Plate XI., Fig. 1), so that they appear like a drag fold with minor contortions. This structure was probably developed by differential movement, whilst the magma was still plastic. The dark minerals in the bands show no parallel orientation, and it is therefore improbable that they represent xenoliths of gneissic rocks.

The parallel bands vary in width from ½ inch to 1 inch, and occasionally swell out into knots 6 inches across. The edges of the bands are not sharply differentiated from the surrounding granite. Associated with them are occasional light-coloured bands, and a pocket about 4 feet across, of a very coarse granite, with an average grain size equal to the phenocrysts in the giant granite, i.e., about 1 inch in length. These are 6 inches to 9 inches wide, and are visible in Plate XI., Fig. 1, just below the curved horizontal joint plane. The pocket is rimmed on its upper edge with a melanocratic band, and is probably connected with the bands of coarse-grained granite. Large phenocrysts of felspar sometimes project into the biotite bands, and clots of biotite occur in the granite.

The normal giant granite occurs above and below the banded zone, while the granite between some of the biotite bands may contain less biotite than the bands, but more than the surrounding giant granite. It is a non-porphyritic granite of grain size finer than the groundmass of the giant granite.

Mineralogy.

The granite has been described (30), as an alkali granite consisting of large phenocrysts of alkali felspar (mainly orthoclase), together with quartz, oligoclase, biotite, hornblende, and small amounts of the accessory minerals apatite and magnetite, and it was stated that there is a large excess of alkali felspar over plagioclase. As shown by the following table of Rosiwal analyses, this is true for the bulk of the outcrop, but at the contact of some of the more basic types of inclusions the two felspars are more nearly equal in amount. In more highly contaminated examples, orthoclase becomes subordinate to plagioclase, and microcline is absent. The phenocrysts of potash felspar occupy a volume percentage of 17.4 in the normal giant granite, as determined from an area of 250 square inches.

TABLE 1.

Mineral.	1.	2.	3.
Quartz	28.7	19.6	17.9
Orthoclase, Microcline, Perthite ..	34.8	21.6	7.3
Oligoclase	25.5	16.6	11.4
Biotite	8.8	32.2	51.3
Hornblende (with residual Augite) ..	1.3	4.8	2.1
Sphene	0.45	1.00	3.08
Orthite	0.05	0.61	3.47
Zircon	0.17	2.87	1.53
Apatite	0.14	0.72	1.92
Ilmenite	0.07	tr.	tr.
Calcite	0.02	..	..

1. Average of seven examples of the giant granite from various parts of the outcrop. The mineral percentages in column 1 have been computed from a combination of phenocryst % and values obtained for the minerals in the groundmass by micrometric analyses.
2. Granite at contact of xenolith.
3. Basic schlieren in the granite at Quarry 1.

The potash felspar phenocrysts are often as large as 3 inches x 2 inches, and consist of orthoclase, vein perthite (albite-oligoclase intergrowth), and platy perthite (albite intergrowth). Although they appear to be single crystals, in thin section they are seen to consist of several individuals which contain inclusions of oligoclase laths, quartz, augite, hornblende, and apatite needles. Nockolds (21, p. 446), considers that inclusions such as these indicate derivation from xenoliths.

A few quartz phenocrysts, up to 1 inch in diameter occur, with strings of dust-like inclusions. The quartz sometimes shows graphic intergrowth with orthoclase.

Microcline is allotriomorphic, interstitial, and frequently microperthitic. Myrmekite occurs as pustule-like intergrowths at the contacts of plagioclase with alkali felspar crystals. Sederholm (28) states that this is a characteristic of granites which have assimilated basic rocks, and Hills (15) suggests it is probably a deuteric intergrowth, resulting from the reconstitution processes going on between the components of the granite magma and xenoliths.

The plagioclase felspar consists of idiomorphic twinned and zoned crystals of oligoclase to andesine.

Biotite contains numerous apatite and zircon inclusions with pleochroic haloes 0.04 mm. in diameter. Reaction rims consisting of granular aggregates of colourless sphene and ilmenite or of sphene alone, are sometimes developed at the contact of biotite with oligoclase. Dactylitic structure occurs within limited areas at hornblende contacts, where the biotite has corroded and penetrated the hornblende, and has become intergrown with quartz thrown out from the reaction. The biotite sometimes contains sagenitic webs of sphene.

Hornblende is an important constituent of the granite. It is pleochroic from brownish- to pale-green, or weakly pleochroic and actinolitic. It is derived mainly from augite, and has been partly altered to biotite, chlorite, and calcite, with associated sphene and ilmenite. Where abundant, it forms individual crystals, clots, and rings, similar to those described by Nockolds (23, p. 503), who considers that such structures are derived from the complete dissolution and disintegration of basic igneous material (a basic greenstone), rather than from sediments. Augite occurs as occasional xenocrysts partially altered to hornblende and biotite. It is often present as residual areas in hornblende. Diopside is represented by infrequent rounded grains and prisms, confined to the proximity of xenoliths.

Lozenge-shaped crystals and aggregates of sphene, strongly pleochroic from red- to yellow-brown or colourless, are sometimes moulded on to oligoclase and hornblende, or else occupy the cleavages of the hornblende.

Apatite occurs both as slender needles and stout prisms. The slender needles are embedded in quartz, felspar, and biotite, and are most abundant in the neighbourhood of clots of hornblende. The stouter prisms have rounded ends, and rarely show pyramidal terminations. They contain inclusions, which may be crystalline, rod-like, and central, elongated along the direction of the c-axis, or may be strings of minute, reddish, bubble-like inclusions, opaque areas of iron oxide, and occasional grains of rutile.

Zircon is an abundant accessory mineral. The crystals are usually colourless, but a few are pale pink and yellow, and others appear sooty, due to many dust-like inclusions (20). Glass-clear forms, free from inclusions, are uncommon (Fig. 2F). Crystal forms present are (*a*) elongated unit prism with pyramid (Fig. 2C); (*b*) first and second prisms and pyramids, sometimes terminated with the basal pinacoid; (*c*) occasional forms with "torpedo" habit (12, p. 223), in which the steep (311) pyramid is prominent (Fig. 2G); (*d*) stout, stumpy prismatic crystals with dominant (111) faces (Fig. 2B); and (*e*) rare parallel growths (Fig. 2D), and geniculate twins. Variations in refractive index cause most of the zircons to show internal striations (Figs. 2A and 2D). The inclusions in individual crystals vary widely in number, and are haphazardly arranged (Fig. 2C). They consist of small rounded colourless cavities, larger cavern-like inclusions, often drawn out in the direction of the c-axis, widening in a bulbous manner near the apices, and occupying the whole length of the crystal. There are also irregular, cloud-like suspensions of opaque dust, hematite scales, foxy-brown rutile rods, biotite blebs, clear granules of apatite, and smaller prisms of zircon. Some of the brown irregularly-shaped occurrences may be liquid in nature (2, p. 28). Most of the zircons are included in biotite, a few occur in orthoclase and hornblende. Large zircons also occur independently of these minerals.

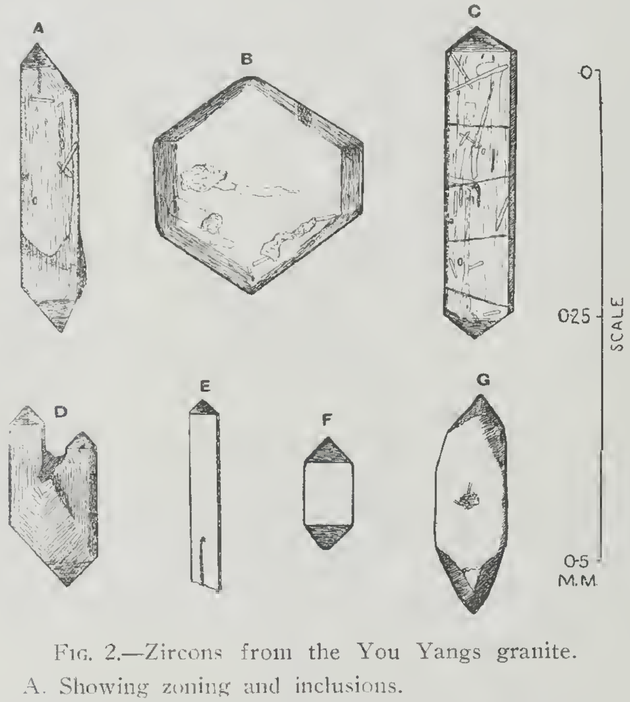

Fig. 2.—Zircons from the You Yangs granite.

A. Showing zoning and inclusions.
B. Stout stumpy type.
C. Showing rod-like, axial and irregular inclusions.
D. Showing parallel growth and zoning.
E. Elongate crystal with axial inclusion.
F. Glass-clear type.
G. Showing pyramid (311) ("torpedo habit").

Orthite is mainly confined to the proximity of xenoliths, reaching a maximum development in the basic schlieren of Quarry 1, where it occurs as diamond-shaped, prismatic, or irregular crystals. It is sometimes zoned, and exhibits irregular cracks, and occasionally simple twinning parallel to (100). In places it is altered to a red-brown, wax-like, or amorphous substance with indefinite optical properties. This alteration develops in the external zones, within which, irregular-shaped areas of the fresher variety, pleochroic from brown to red-brown, may be present. When in contact with biotite, it is surrounded by pronounced pleochroic haloes, 0.04 mm. in width, this value being the range of penetration of Thorium C_2 (17). Inclusions in the orthite are zircon, apatite, crystallites of iron oxide (in the altered outer parts), and occasional plates of hornblende. The orthite has a variable birefringence, an average extinction angle of 34°, and the size of the crystals varies from 0.30 x 0.35 mm. (diamond-shaped), to 2.85 x 0.40 mm. (prismatic).

Chlorite (probably penninite), replaces both biotite and hornblende, and often contains sprays and sagenitic webs of ilmenite. Calcite is rare, as occasional rhombs 0.30 mm. in size, as granular cores in oligoclase, and replacing hornblende. Sericite is a common alteration product of the cores or entire crystals of felspar, and muscovite is secondary after oligoclase. Pyrite, chalcopyrite, and pyrrhotite are rare, and rutile, probably derived from included sediments, occurs as small rounded grains and prisms. Heavy mineral determinations support the conclusion (30, p. 5), that magnetite is almost completely absent. The small amount present may be primary, or derived from the assimilation of xenoliths.

In many respects, the You Yangs granite resembles the description given by Nockolds (21) of the Bibette Head granite. There is a similar variable concentration of hornblende, association of sphene and apatite needles with the clots of ferromagnesian minerals, abundance of apatite included in biotite, chloritization of biotite, scarcity of magnetite, and a high index figure, all of which Nockolds regards as indicating a contaminated granite. Groves (12, p. 222) also states that higher index figures are due to assimilation accompanied by increased production of biotite.

The coarse-grained granite of Quarry 1, consists of abundant orthoclase and microcline-perthite with some quartz, oligoclase, biotite, and a small amount of sphene, these minerals resembling those in the giant granite.

Heavy Mineral Indices and Assemblages.

In the preparations for the study of the heavy minerals, the samples were crushed and quartered, passed through a 0.5 mm. brass sieve, washed free of very fine dust, dried, and weighed. The weight of sample treated was from 15 to 20 grams in each case, and separation into light and heavy fractions was effected in bromoform of sp. gr. 2.88. The ratio of heavy to light minerals gives the index figure.

The heavy mineral assemblage in the You Yangs granite is constant as far as mineral species are concerned, the suite of minerals being—

Primary essential minerals—biotite and hornblende (in part).

Primary accessory minerals—zircon, apatite, magnetite, and some sphene.

Secondary or Contamination minerals—augite, diopside, orthite, rutile, pyrite, chalcopyrite, pyrrhotite, chlorite, and some sphene, ilmenite, hornblende, and biotite.

Secondary alteration minerals—muscovite, limonite.

Pneumatolytic accessory minerals are entirely wanting.

Twelve samples from various parts of the You Yangs outcrop have shown a fairly constant sp. gr. and index figure, the averages being 2.65 and 13.1. One instance occurred where the percentage of phenocrysts was greater than the average, and the index figure was then as low as 7.9. No general relationship was observed between the sp. grs. of samples and corresponding index figures.

Biotite plays the most important part in index figure variations, followed by hornblende and sphene, whilst apatite and zircon are relatively evenly distributed, so that the range in values from 10.9 to 18.4 is due to the greater abundance of ferromagnesian clots in some of the samples.

Relations to Neighbouring Granites.

It has been suggested that the You Yangs granite is connected beneath the plains of basalt with other smaller outcrops occurring to the north, west, and west-south-west (30), indicated in Fig. 1.

Although specimens from the more important of these outcrops and from the east-west tongue at the north-west corner of the You Yangs outcrop are similar in the hand specimen, except for hornblende in the main You Yangs outcrop, the examination of thin sections and the heavy mineral indices and assemblages indicate certain variations (Table 2).

Table 2.

Location.	Sp. Gr.	Index Figure.
1. You Yangs (main mass)	2.65	13.1
2. West end of east-west tongue in north-west of You Yangs area	2.63	8.6
3. Anakies (main outcrop)	2.63	4.9
4. South Anakies	2.63	4.6
5. Yowang	2.63	6.5
6. Darriwil	2.63	5.9
7. Dog Rocks	2.62	3.6

Aplites are associated with both the You Yangs and Western (Nos. 2 to 7) granites, but xenoliths, schlieren, and clots of ferromagnesian minerals are absent in the latter. There is a greater abundance of biotite in the main You Yangs granite. Hornblende, orthite, calcite, augite, diopside, and rutile have not been noticed in the Western outcrops, while, on the other hand, the main Anakies granite contains purple fluorite, and the Yowang outcrop occasional blue tourmaline. Chloritization and bleaching of biotite, and sericitization of felspars are more pronounced in the Western outcrops, but microline and myrmekite are more rare, and quartz more common. Pyrite, pyrrhotite, chalcopyrite, and magnetite are rare in all cases, and apatite is similar throughout, except that the small needles are represented in the main You Yangs mass only. Sphene is rare and colourless in Western occurrences, but very abundant in the You Yangs granite. In the Western outcrops, zircon shows noteworthy differences, pale yellow crystals with first and second prisms and pyramids with prominent basal pinacoid being common. The glass-clear, zoned, twinned, "torpedo" type, and stout stumpy crystals of the You Yangs are rare, inclusions not nearly as abundant, the terminations never as acute, and the size hardly ever equal to those of the You Yangs zircons.

It appears from these observations, that if all the occurrences are comagmatic, the You Yangs type represents a more active part of the intrusion which produced a different crop of zircons. The greater amount of heavy constituents (mainly ferromagnesian minerals), indicates more extensive assimilation and contamination than obtained in the Western outcrops.

Jointing.

(Note.—Values cited for the strike of joints and dykes are magnetic bearings; the declination for Melbourne is $8\frac{1}{4}°$.)

The joints in the granite are numerous and well brought out by erosion. Aerial photographs of the granite, taken by the Defence Department, show that the trend of outcrops, as at Big Rock and the Precipice, and the general parallelism of the gullies, are controlled by master joints striking W. 20° N., and N. 30° E., the former set being the more strongly developed.

Of about 650 measurements of the strike of joint planes made in the field, almost one-half of the number corresponded with these two general directions. The measurements have been plotted in the accompanying strike frequency diagram. (Fig. 3.)

The dip of the master joints varies from 86° to 90°, and they are usually vertical, whilst the dip of the subsidiary joints varies between 76° and 90°.

Horizontal ("sheeting") joints (35) control the development of flat outcrops and dome-shaped tors; these joints are usually

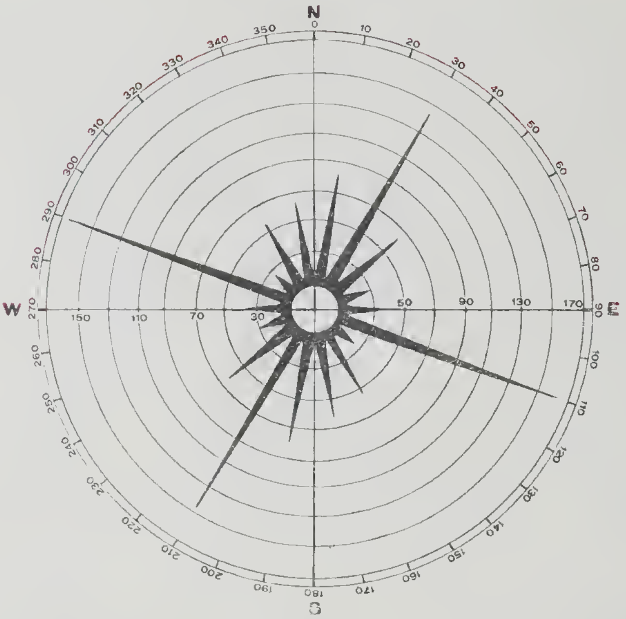

FIG. 3.—Strike frequency diagram of the joints of the You Yangs granite. (Figures along the east-west axis indicate the number of measurements made of the strikes of series of parallel joint planes.)

gently curved upwards or downwards, and are occasionally sigmoidal. (Plate XI., Fig. 1.) Some dip at 17° from the horizontal, e.g., as at the Precipice. They are parallel to the surface of the north-north-east slopes of Flinders Peak, thus indicating that they played an important part in the development of the present angles of slope of Flinders Peak. According to Bucher (quoted in 35), these joints would be due to internal stresses arising from shrinkage incidental to cooling, and Wilson (35), places them amongst the earlier formed joints "produced when upward movement of the highly viscous magma produced secondary tensional stresses in the previously crystallized outer portion of the intruded body."

The joints of the granite can often be traced through xenoliths and aplite dykes (Plate XI., Fig. 2), but occasionally they terminate abruptly on either side of the walls of the latter, so that some of the joints may be structural, arising from subsequent earth movements, the compressive stresses being applied in different directions, chiefly east and west, probably during the late Palaeozoic.

There is no relationship between the joints in the granite and structures in the country rock, and the hidden contact of the granite presumably transgresses the strike of the altered sediments.

Excellent jointing occurs in aplite dykes. A 10-ft. dyke on the south-western slopes of P.1 shows in plan 22 joints, 3 inches to 6 inches apart, all parallel to the strike (N. 5° W.) and dip (77°) of the walls of the dyke, with smaller cross joints at right angles to them. Aplite dykes exposed on the vertical faces of granite tors, exhibit a set of shrinkage joints normal to their walls. Rhomboidal jointing is present in the irregular intrusion of aplite on the south-eastern flanks of P.6. (Plate XI., Fig. 2.)

In porphyry dyke D.2, on the south-western slopes of P.2, there are 13 joints about 18 inches apart, all parallel to the strike (S. 13° W.) and dip (82°) of the walls of the dyke, while in porphyry dyke D.1, small joints are relatively well developed, having a general strike of W. 45° N., and a dip of 85°.

The Xenoliths in the Granite.

Field Distribution.

Abundant dark and light-grey patches of included foreign material occur throughout the whole area of giant granite at the You Yangs. They are locally concentrated near Mount Rothwell homestead, on Little Hills, where, at the base of a granite tor, 125 xenoliths occur in an area of 10 feet x 2 feet. The isolated granite outcrops to the west and north-west, and the east-west tongue at the north-western end of the You Yangs are almost entirely free from xenoliths.

Xenoliths of definite outline vary from ½ inch x ½ inch to 6 feet x 12 feet in size. Many show sharp contacts with the granite, while some exhibit irregular contacts (Fig. 4D), with a more or less gradual passage into the lighter coloured granite (Fig. 4A). They grade from angular to rounded or embayed shapes, and, on erosion, project from the granite surfaces, or weather out, leaving irregular and smooth round hollows.

Sedimentary and igneous xenoliths are represented, and provide good examples of "inshot" inclusions (3). The less altered sedimentary types often show several narrow parallel veins of granitic material which has been injected along planes of weakness. The inshot veining may also be irregular, and the assemblage of 125 xenoliths at Mount Rothwell may represent the breaking up of a large included block by the invading magma. A mingling of granitic and xenolithic material occurs in these veins (Fig. 4B). Embayed types often show an abundant development of biotite in the bays, but the biotite is not so common at unembayed contacts. (Fig. 4C.)

Very fine, even-grained, dark-coloured types representing altered argillaceous rocks, are small in size, and not abundant. They often tend to be schistose, and form drawn-out patches in the granite, sometimes 9 inches long and 1 inch wide. Occasionally, small white spots appear in these dark types.

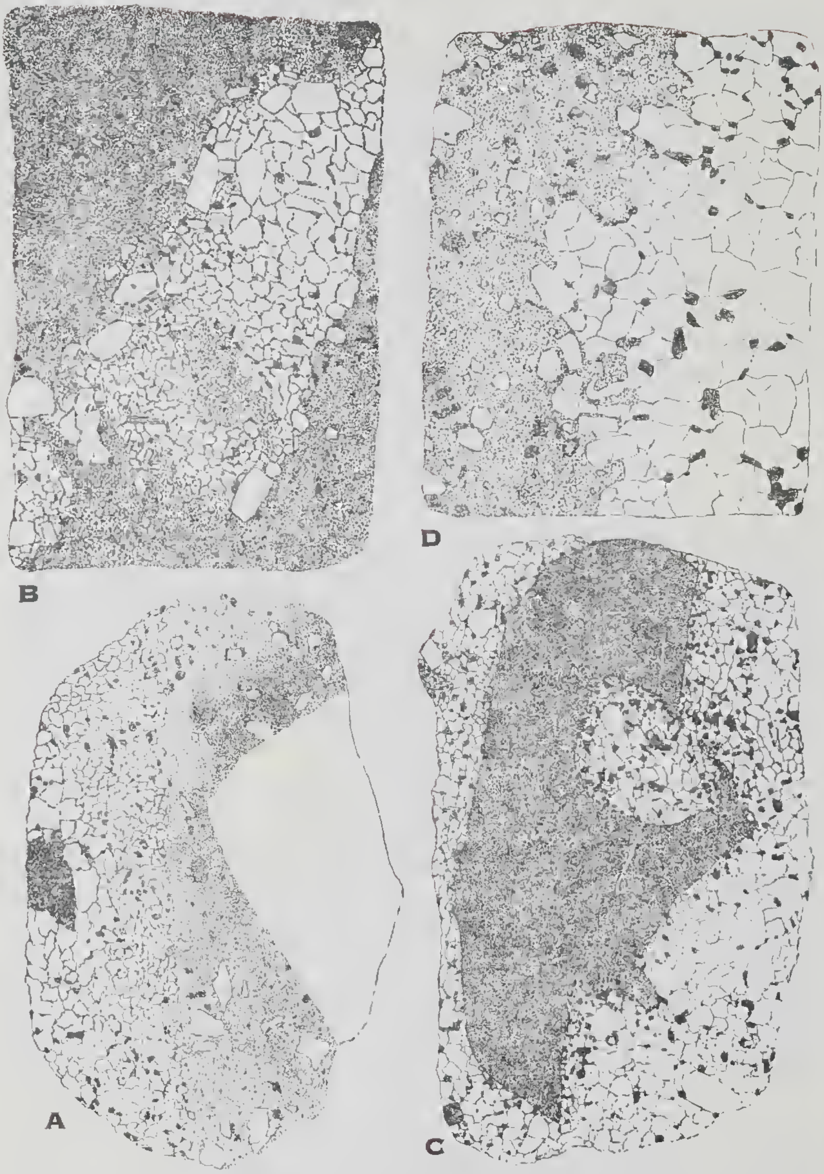

FIG. 4.—Xenoliths from the You Yangs granite.

A. Contact of Quartzite and Biotite-rich xenolith, the latter passing outwards into a medium-grained hybrid granite containing clots of biotite.

B. "Inshot" inclusion showing mingling of granitic and xenolithic material.

C. Plan of a block 2 in. by 2 in. by $1\frac{1}{2}$ in. showing an embayed xenolith containing occasional fine threads of granitic material, and the abundant development of biotite within the bays.

D. Showing advance of granite on a granitized biotite-rich xenolith, and the development of xenolithic "strew."

The most abundant xenoliths are porphyritic types rich in ferromagnesian minerals, which impart a dark-grey or greenish colour to the rock. Occasionally, as in the bed of Sandy Creek, a light-coloured felsic type is observed which consists of visible poikiliths of quartz and felspar flecked with small plates of biotite. Such structures are more frequently micropoikilitic. Examples consisting entirely of fine-grained leucocratic minerals are rare.

The xenoliths as well as the granite, are occasionally cut by aplite veins, and in all such instances well defined contacts are observed.

Group 1.—Xenoliths of Sedimentary Origin.

These are not very common, and are represented by (*a*) fine-grained, sometimes schistose, biotite-rich rocks, and (*b*) quartzitic rocks.

(*a*) *Fine-grained, Biotite-rich Rocks.*—The abundant presence of biotite in this group is ascribed to the commutation of mafic and aluminous material contained in mudstones and shales. The development of corundum is regarded as indicating the presence of sedimentary types (shales, &c.), which were very rich in alumina (25, p. 450).

The xenoliths are dense, dark, fine-grained varieties consisting of abundant small flakes of biotite characterized by numerous pleochroic haloes with a diameter of 0.04 mm., and usually having no visible nucleus. Some of the haloes are dense black, with clearly defined outlines, some have small black centres, and light outer rims with indefinite borders, and others broad dark centres, with narrow light coloured rims. In shape, they are circular, or elliptical where the nucleus mineral is elongated along one axis, whilst coalescence of several haloes occurs where they are numerous and crowded. The small flakes of biotite are sometimes in parallel alignment, representing either original structures of the inclusion, or resulting from thermal metamorphism. In no case is schistosity well defined (Fig. 5A). Alteration of biotite to chlorite is accompanied by radial needles and irregular aggregates of ilmenite.

Sphene is rare, while small rounded grains of rutile and zircon are not uncommon. Granules, rods and needles of apatite, and minute blebs of biotite occur in a base of quartz, orthoclase, occasional oligoclase and interstitial microcline. Iron ores are rare.

A variation in this type of xenolith consists of those which contain white spots, seen to be knots of muscovite arranged in sheaves around a nucleus of granular corundum, pleochroic from blue to colourless. They resemble occurrences figured by Gardner and Reynolds (11), whilst Read (25, p. 447), records relics of corundum persisting in a micaceous product resulting from the alteration of the corundum. Sometimes the corundum contains included magnetite or ilmenite. In some cases, the aggregates of muscovite contain no nucleus of corundum, and probably represent a complete alteration product of the corundum.

Contacts with the adjoining granite may be either well defined or irregularly embayed. The grain size of the xenoliths often becomes coarser as the granite junction is approached, and the microcline of the granite becomes flecked with xenolithic "strew" producing poikilitic structure. The parallel bands of granite that develop in the inshot xenoliths of this group consist of narrow veins of orthoclase and microcline, or of intergrown orthoclase and subordinate quartz, with rare idiomorphic oligoclase.

(*b*) *Quartzitic Rocks.*—A few xenoliths of quartzite which, when very fine-grained and porcellanous in texture, have the appearance of baked cherts, occur on the south-western side of P.11, and at Quarry 2. They represent arenaceous sediments in which the original quartz has recrystallized to numerous small interlocking grains with abundant minute inclusions. Zircon is rare and rounded, and minute rutile grains occur interstitial to the quartz and diopside. The quartzite xenoliths show sharp boundaries when in contact with biotite-rich xenoliths (Fig. 4A), and they become slightly coarser in grain at granite contacts. A distinct line of contact is visible in sections of the junctions with altered argillaceous inclusions, and such occurrences suggest quartzite pebbles which have remained unaltered relative to the argillaceous base in which they were set.

A somewhat darker type of quartzitic rock, produced from a more argillaceous sandstone or quartzite, contains more biotite, abundant grains of iron oxide, and occasional patches of garnet.

Group 2.—Xenoliths of Igneous Origin.

Xenoliths included here are considered to be of igneous origin on account of the abundance of clots and large plates of biotite and hornblende, the presence of shreds of diopside, abundant sphene, the occurrence of residual ophitic structures, and the alteration of xenocrysts of augite to hornblende and biotite. The occurrence of hornblende as clots and rings indicates derivation from basic igneous material (Nockolds, 23, p. 503).

The hornblende-rich xenoliths of this group which have been derived from incorporated fragments of diabase and epidiorite, offer many resemblances to the acid hornblende hybrids described by Deer from the Cairnsmore igneous complex (8). The least altered examples with diabasic affinities sometimes contain residual augite, and sometimes show a residual ophitic structure but no augite. When granitization commences, original structures disappear and the xenoliths grade from types showing more advanced reconstitution, to those which have developed porphyritic textures by the mechanical introduction of pools of quartz and felspar. The final stages produce types in which granitic textures become prominent.

Examples which contain large areas of actinolite and augite altering to secondary amphibole, may represent included fragments of a coarse-grained epidiorite, such as occurs in the Geelong district (6), because the augite of the epidiorite of Ceres, near Geelong, shows a similar alteration, with the production of large areas of fibrous actinolite.

Some of the finer grained xenoliths of this group may, as suggested by Joplin (18), be due to the grain-size reduction of coarse-grained igneous rocks by the disruption of highly poikilitic hornblende and biotite—these minerals show crenulation and sieve structures in the You Yangs xenoliths of igneous origin—and by the formation of granular masses of pyroxene and criss-cross flakes of biotite—decussate structures in biotite are present at the You Yangs—during hybridization.

The igneous xenoliths are nearly twice as abundant as all other xenoliths collectively. They vary in texture from fine-grained to porphyritic and include (*a*) hornblende-rich xenoliths, and (*b*) diopside-rich xenoliths, biotite being relatively common to both. (*a*) Hornblende-rich types. The dominant ferromagnesian mineral is a pale-blue- to yellowish-green hornblende, often weakly pleochroic, fibrous, and actinolitic. The hornblende is occasionally brownish-green. It is mostly secondary after augite, with inclusions of zircon, and ilmenite and sphene along cleavages. Individual crystals with crenulate margins, and irregular areas and nests, are usually associated with internal residual grains of augite, and an exterior rim of biotite flakes.

Biotite is more common than diopside, both being subsidiary to hornblende, and in one instance, actinolitic amphibole is present to the complete exclusion of these two minerals. Biotite occurs as plates of varying size, in decussate and sieve structures, as occasional clots, and as dactylitic intergrowths. The colour is usually yellow to greenish-brown, and some blood-red plates are also present.

Diopside is rounded, granular or prismatic, and colourless to pale green, similar to diopside in (*b*). Augite is present as twinned crystals showing no alteration to hornblende, and may contain small plates of biotite along the cleavages.

Sphene is relatively abundant as small grains and larger crystals. It is frequently associated with hornblende and often moulded on to the felspars and hornblende (Fig. 5F). Orthite is not common, and is mainly irregular in shape (Fig. 5B), although occasional eight-sided crystals 0.5 x 0.3 mm. in size occur. Numerous colourless needles of apatite, often over

1 mm. long, and 0.1 mm. broad, are included in the other minerals (Fig. 5c). They sometimes possess a central cavity extending along the length of the crystal. Stouter prisms with granitic affinities are rare. Zircon occurs as small inclusions in biotite, and nearer granite contacts, as larger crystals similar to those in the granite.

Ilmenite and sphene are present in reaction rims at biotite-felspar contacts. Pyrite, chalcopyrite, and pyrrhotite, are rare, limonite and hematite are developed along cracks and cleavages. The occurrence of calcite is limited. It may be interstitial or secondary after hornblende.

Of the colourless minerals comprising the base of the rock, quartz may be only interstitial or it may form practically the whole of the base. Lobate growths and irregular patches in optical continuity are not uncommon (Fig. 5D), and pools, often associated with orthoclase, are surrounded by rings of ferromagnesian minerals. In one instance, a quartz pool is accompanied by chalcopyrite and pyrrhotite. Quartz may also be radially intergrown with orthoclase and oligoclase.

Oligoclase occurs as idiomorphic laths and phenocrysts, which are occasionally poikilitic, carrying flakes and blebs of biotite. It sometimes forms clear rims to crystals of cloudy felspars, giving rise to "jacketed" types (14), the cloudiness of which is due to sericitization and limonitization of earlier formed laths.

Zoning may arise either from changes in the composition of the magma as it was introduced into the xenolith, or from the presence of rings of minute inclusions caught up during various stages of crystallization of the oligoclase.

Labradorite occurs in partially reconstituted xenoliths. Albite is occasionally present as pellucid laths and zoned phenocrysts, and as rare poikiliths.

Orthoclase, turbid through sericitization, is sometimes poikilitic, or perthitic, and present as small inclusions in optical orientation in poikilitic microcline. Myrmekite is present in small amount. Microcline and orthoclase are subordinate to oligoclase and quartz.

At granite contacts, these xenoliths are usually embayed, though their junctions may be well defined. The felspars of the granite at contacts are often flecked with inclusions of undigested mineral fragments derived from xenoliths, while augite, hornblende and biotite crystals appear to have floated out into the granite.

(*b*) *Diopside-rich Xenoliths.*—Pale green to colourless diopside crystals are abundant and dominate biotite and hornblende. The diopside is present as strings and aggregates of rounded grains, stumpy prisms, and elongated shreds, with iron oxide along cracks and cleavages. Rings of diopside surround pools of quartz and felspar. Reynolds (26, p. 609) records similar structures in the Newry igneous complex, and states that as the porphyroblasts grew, they swept the ferromagnesian minerals to one side.

A reversal of the normal change, pyroxene to amphibole, occurs where secondary amphibole (actinolite), has been replaced by diopside. This is probably the result of increased thermal metamorphism of the hornblende-rich xenoliths.

Myrmekite, orthite, zircon and sphene are much less common than in (*a*). Oligoclase is sometimes intergrown with orthoclase, giving rise to a "blocky" structure. The amphibole is mostly actinolite, and rarely tremolite.

In other characteristics this class of xenoliths resembles the hornblende-rich types.

Group 3.—Xenoliths of Doubtful Origin.

These are coarser in grain than the sedimentary xenoliths, and show no tendency towards schistosity. They have fine- to medium-grained, porphyritic, and fine-grained granitic textures.

The presence of rounded zircons and the rarity of hornblende and diopside suggest that they may represent advanced stages in the granitization of xenoliths of sedimentary origin, but no intermediate types between them and those of group 1 have been found. Some possess a "granulitic" microstructure (3, p. 202), and may therefore have a sedimentary parentage (26, p. 22).

Some contain hornblende and diopside, but not as the large plates and prisms characterizing xenoliths of undoubted igneous origin. These minerals may be formed from the femic material in impure sediments. On the other hand, these xenoliths may represent acidfied igneous types in which fine-grained textures have developed in the manner described by Joplin (18). Fig. 5E is a sketch micro-section of a typical example of this class of xenoliths. Corundum is absent, hornblende and diopside are developed in a few cases.

Aggregates of biotite, often bleached, have developed as small clots showing sieve structure and decussate arrangement, which is highly characteristic of thermally metamorphosed rocks (13, p. 35). Sometimes, large plates of biotite are surrounded by a swarm of smaller flakes, which project from the edges of the large plate. This structure resembles that described by Sederholm (27, p. 5), in which optically continuous plates of biotite, called "porcupinitic" biotite, project from the ends of augite crystals. Reaction edges to biotite consist of fringes of sphene, sometimes with ilmenite, and are similar to those described by Nockolds (23), as reaction products between titaniferous biotite and the felspathic material of the magma.

Orthite is rare, generally altered, and apatite needles are numerous. Rounded grains of zircon are thought to be xenocrystal, representing stable remnants of included impure arenaceous sediment. Ilmenite occurs as small rods and grains scattered throughout the rock.

The light coloured minerals often occur as fine granular areas associated with coarser grained streaks and patches (Fig. 5G), and as phenocrysts or large irregular areas forming an interlocking base. Quartz is common, radially intergrown with orthoclase, or as large areas in optical continuity which enclose and wrap round the other minerals of the rock (Fig. 5D). Pools of quartz may be free from inclusions or flecked with biotite. Laths and poikiliths of oligoclase occur, and porphyroblasts contain small intergrown areas of microcline, with a structure in which each half of a zoned Carlsbad twin possesses lamellar twinning along the lamellae of which are intergrowths of orthoclase or microcline (1). Inclusions of biotite, chlorite, quartz and apatite are also present

Microcline is interstitial, often poikilitic, and intergrown with quartz. Myrmekite pustules occur at microcline-oligoclase contacts. Orthoclase is sparse, and usually turbid from sericitization.

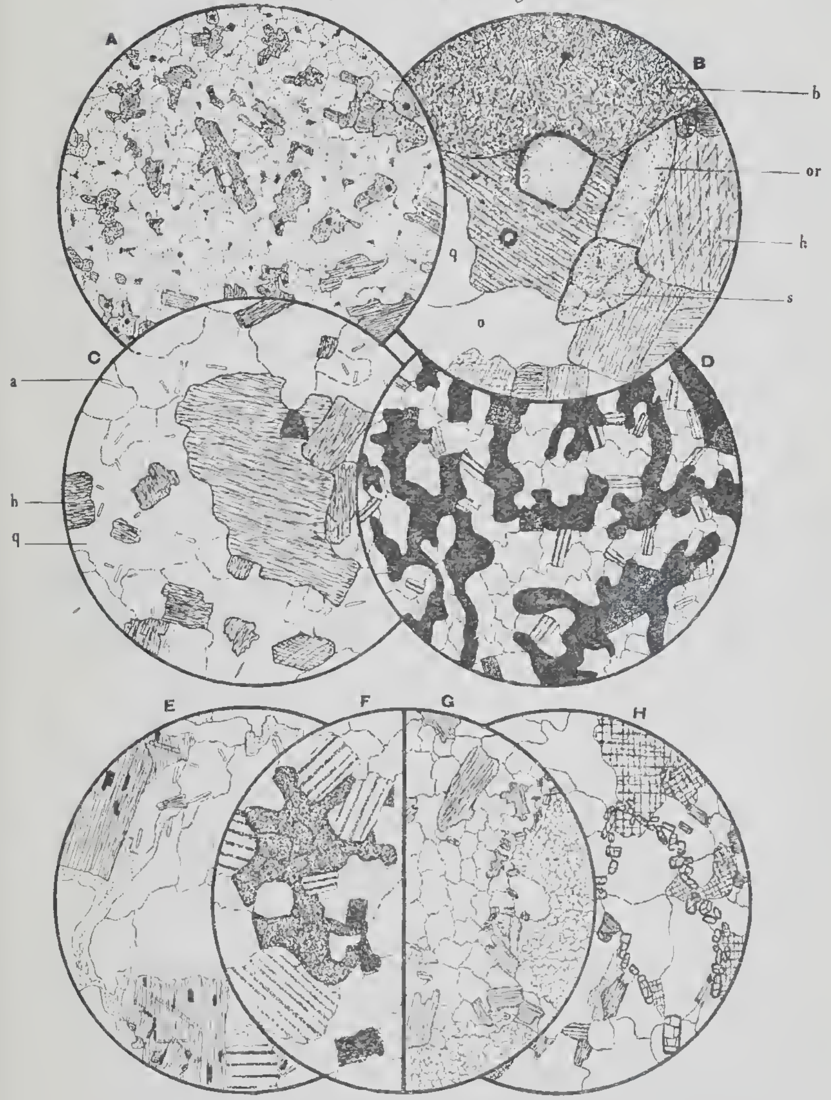

FIG. 5.—Sketch micro-sections of the xenoliths occuring in the You Yangs granite.

A. Fine-grained biotite-rich type of sedimentary origin.
B. Hornblende-rich type of igneous origin. (or-orthite, s-sphene, b-biotite, h-hornblende, o-oligoclase, q-quartz.)
C. Hornblende-rich type with abundant rods of apatite, the hornblende mainly converted to actinolite (a-apatite, h-hornblende, q-quartz).
D. Lobate areas of quartz (black) in optical continuity.
E. Biotite-rich type of doubtful origin. Large plates of biotite contain ilmenite along cleavages, orthoclase (stippled), is interstitial, and apatite rods are common.
F. Sphene (dark stippling) wrapped around oligoclase (banded shading), quartz (colourless), biotite (dark), and orthoclase (light stippling).
G. Biotite-rich type, probably of sedimentary origin, showing the development of coarser-grained patches.
H. Diopside-rich type containing a quartz-microcline pool surrounded by a ring of diopside.

The Heavy Mineral Indices and Assemblages of the Xenoliths.

The heavy mineral indices and assemblages of the different groups of xenoliths are shown in Table 3. A wide range of index figures is shown by the xenoliths of igneous and doubtful origin (Groups 2 (*a*), 2 (*b*), 3), and is due to the variable amounts of biotite, hornblende and diopside. Sphene, zircon and apatite are present in all types. Orthite is absent from, and sphene rare in the sedimentary xenoliths, (Groups 1 (*a*) and 1 (*b*)), whilst corundum is confined to Group 1 (*a*). Garnet occurs sparsely in Group 1 (*b*) and, like corundum, does not occur in the granite.

Table 3.

Heavy Mineral Assemblages of the Groups of Xenoliths.

Xenolith Group.	Average Specific Gravity.	Range Specific Gravity.	Average Index Figure.	Range Index Figure.	Biotite.	Actinolite and Hornblende.	Diopside.	Augite.	Sphene.	Zircon.	Apatite.	Orthite.	Corundum.	Magnetite.	Ilmenite.	Pyrite.	Pyrrhotite.	Chalcopyrite.	Hematite.	Limonite.	Garnet.	Rutile.
1 (*a*)	2.70	2.68 to 2.73	11.6	9.6 to 13.5	A	V	..	..	r	o	C	..	a	r	o	..	..	..	C	o	..	V
1 (*b*)	2.64	..	2.3	..	(V)	(r)	o	..	(r)	(V)	(o)	..	..	..	..	..	..	..	..	r	o	V
2 (*a*)	2.70	2.65 to 2.84	23.5	8.5 to 41.7	a	A	o	o	a	o	a	o	..	r	o	r	r	r	o	o	..	V
2 (*b*)	2.75	2.68 to 2.84	25.3	17.4 to 42.0	a	a	A	C	C	V	A	V	..	r	o	..	..	..	o	C	..	V
3 ..	2.69	2.68 to 2.72	22.8	8.3 to 40.9	A	r	V	V	C	o	A	r	..	r	C	..	..	..	..	o	..	V

A—very abundant ; a—abundant ; C—common ; o—occasional ; r—rare ; V—very rare.

The symbols in brackets in Group 1 (*b*) indicate that the minerals were only observed in rock sections near junctions with granite or hybridized xenoliths. Group 1.—Sedimentary Origin. Group 2.—Igneous Origin. Group 3.—Doubtful Origin.

Basic Schlieren.

The occurrence and associations of basic schlieren have been described when considering the field occurrence of the You Yangs granite. They consist of biotite, zoned oligoclase in excess of orthoclase, clear quartz with undulatory extinction, and hornblende showing dactylitic intergrowth with biotite. The biotite is exceedingly abundant, with numerous inclusions and pleochroic haloes. Reaction fringes of granular sphene and ilmenite are common, and double-ended, wedge-shaped crystals of sphene are also present. Chlorite occurs after hornblende and biotite, and muscovite, as small secondary flakes, after some of the felspars. Orthite, the most interesting mineral developed in these schlieren, constitutes 3.47 per cent. of the volume. It forms larger and more abundant crystals than in any of the other types of rocks at the You Yangs.

The average sp. gr. of the basic schlieren is 2.95, and the average index figure 54.8. The heavy mineral assemblage consists mainly of biotite with some hornblende, and orthite, sphene, apatite and zircon, similar to types represented in the giant granite.

The fact that some of the xenoliths at Quarry 1, where basic schlieren are best developed, are stretched out, points to the possibility of the bands being formed by further drawing out and granitization of the included rock. Sederholm (28, p. 99) considers that striping in granite results from inclusions of foreign rock which have been more or less completely resorbed, and whose femic constituents remain as stripes of black mica with a small amount of unchanged hornblende.

Hybrid Types.

Hybridized inclusions comprise those which, by advanced granitization, have lost all resemblances to the described types of xenoliths, but have not acquired the texture of the giant granite, although a few examples approach closely to it. They are restricted in occurrence, and never exceed 3 feet across, except at Quarry 1, where they are present as bands between the basic schlieren. They are much finer in grain than the groundmass of the giant granite, and are mostly non-porphyritic.

A microgranite which contains all the constituents of the typical granite, except hornblende and orthite, occurs on the western side of the Rock Basin on Big Rock. In other examples, the texture varies from fine- to medium-grained, and orthite, sphene, sericite and chlorite are present, with more abundant zircon and hornblende. Biotite plates are larger, and contain more inclusions and haloes. The quartz is occasionally diamond-shaped and vermicular, and finer-grained interstitial quartz and felspar occur between larger crystals of the same minerals.

Fine-grained granite hybrids are sometimes met with on the eastern slopes of P. 8. They often merge into porphyritic granite in one direction, and porphyritic xenolith in the other direction. Some examples, however, have well-defined boundary lines against the granite. Fig. 4A indicates the relationship between a medium-grained hybrid granite and a biotite-rich xenolith.

The sp. gr. of the hybrids is 2.63, and their index figures vary from 6.2 to 13.5, the value depending on the original parent of the hybridized inclusion, or on the degree to which the xenolith has been absorbed by the granite magma.

The non-porphyritic granite of Quarry 1, which is associated with the basic schlieren, is a good example of a hybrid granite. It is composed of abundant biotite, plagioclase in excess of orthoclase, quartz, sphene and numerous needles of apatite, but lacks the microcline so typically developed in the giant granite. It has been produced by increased granitization of the basic schlieren.

Contamination and Hybridism.

During the assimilation of invaded sediments and igneous rocks, granite becomes contaminated and basified by the addition of augite, sphene, diopside, hornblende and biotite (29, p. 70). Taylor and Gamba (32, p. 358) record augite and hornblende from the Oatland granite as contamination minerals derived from a basic rock (gabbro). They also state (p. 367), that it is impossible to tell with respect to sphene, how much is primary and how much is secondary. The same statement applies to biotite.

The xenoliths, which represent the arrested stages in a complex reconstruction scheme where a two-way migration is occurring, have become more acid through progressive granitization, giving rise to hybrid types (3).

Several gradational stages of xenolithic dissolution are exhibited as the granite magma has penetrated the xenoliths—(*a*) angular xenoliths, consisting in part of the original material, show a certain amount of recrystallization indicative of thermal metamorphism, but retain remnants of original structures (e.g., residual ophitic structure in diabase inclusions). (*b*) Rounding of the included blocks, and introduction from the granite of porphyritic crystals and pools of minerals which become poikilitic, as described by Quirke and Collins (24, p. 47). The sharp contacts of some examples, where reaction seems to have been absent, may be due to the fact that local convection currents in the magma constantly removed the products of reaction at the surface of the xenolith until, finally, both assimilation and flowage were arrested by viscosity (29). The dark rims at the edges of some of the xenoliths are due to the aggregation of the ferromagnesian minerals produced there. Irregular embayment by the granite (Fig. 4D), with small fragments of the xenolith dispersed through the adjacent granite as "strew" (3, p. 212), (*c*) Penetration of the granite magma along planes of weakness in the xenoliths and the development of "inshot" inclusions (3, p. 212), as in Fig. 4B. Growth of these veins of granite resulting in the breaking up and drifting away of isolated fragments of the xenolith. (*d*) Development of hybrid types with granite textures, which grade into (*e*) faded or ghostly remnants of xenoliths. Indistinct spottedness in the granite, produced by the strewing about of the clots of ferromagnesian minerals, represents the last stages of dissolution of the xenoliths.

When granitization is far advanced, the altered fragments have acquired definite granitic textures, and it is then difficult to distinguish the parent type from which such a hybrid was developed. A hybrid mode of origin is indicated by the following features:—(i) Dusty appearance of some of the felspars due to numerous small inclusions. (ii) Felspars altering to secondary micaceous minerals. (iii) Recrystallization of quartz tending to develop hexagonal and diamond-shaped areas. (iv) Development of shreds of ferromagnesians, and their further growth (24, p. 52). (v) Development of coarser-grained streaks and patches, and micrographic intergrowth of quartz and felspar, indicating increased molecular mobility and a tendency to recrystallize (24, p. 49). (vi) Development of the accessory minerals sphene, apatite, and zircon (24, p. 53). (vii) Growth of quartz and felspar with a diminution of the groundmass. These features (see Quirke and Collins, 24) can be recognized in the hybrid rocks and some of the more granitized xenoliths at the You Yangs.

In the field, the passage from porphyritic xenolith through fine-grained hybrid, and medium-grained granite, to porphyritic granite, is accompanied by a gradual reduction in the volume of the xenolith due to the encroachment of the reaction zone, in which the hybrid type is developed (Fig. 4A). There is a colour change as well as a textural change, the hybrids becoming lighter in colour as more leucocratic constituents are introduced from the granite.

Some of the xenoliths of Group 3, which contain a little hornblende and diopside, may represent advanced hybridization from hornblende- and diopside-rich types of igneous origin, for they often present characteristics which Thomas and Campbell Smith (33, p. 278) regard as probably indicating progressive acidification of hornblende-rich xenoliths. These characteristics are:—The formation of biotite at the expense of hornblende, the absorption of early formed felspars, and a new growth of alkaline felspars, the occurrences of sphene around magnetite and ilmenite, and a general development of small patches of myrmekite.

It has been found that orthite in the granite is usually confined to junctions with xenoliths. Since orthite crystals have been noted within the xenoliths, and abundantly in the basic schlieren, it is possible that the orthite at the You Yangs is a contamination mineral formed as a result of thermal metamorphism.

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Corundum and garnet which occur in the xenoliths, and andalusite which occurs in the country rock, have not been found in the granite. Their absence is due to the fact that their alumina was made over to the potash felspars which are so prominently developed in the giant granite.

The Invaded Rocks.

Only a few small outcrops remain of the igneous and sedimentary rocks into which the granite has intruded.

The igneous rocks are found in the north of the area as a few small boulders of diabase (5) which resemble other Victorian diabases (e.g., Romsey), regarded as Cambrian in age. No contacts with the granite are observable. On account of the resemblance of some of the igneous xenoliths to altered diabase, the boulders are considered to be either a large weathered out, non-granitized xenolith, or the remnants of a roof pendant. Occasionally, introduced phenocrysts of oligoclase with inclusions of secondary amphibole, indicate infiltration of some granitic material. Very thin films of pyrrhotite are sparsely developed along some of the joint planes, and biotite is also present. The sp. gr. is 2.98, and the index figure 83.4, the heavy mineral assemblage consisting of abundant uralite, magnetite, occasional biotite, and rare pyrite and pyrrhotite.

The sedimentary rocks in the south-western corner of the area are thermally altered arenaceous and argillaceous types, which have been described by Skeats (30). A residual pebble of similar material was found on the floor of Quarry 2.

The heavy mineral assemblage of these altered sediments consists of small brown plates and bleached flakes of biotite, rare clear rounded grains of zircon free from inclusions and zoning, prisms and irregular grains of greenish-brown tourmaline, rounded grains and occasional prisms of foxy-red and yellowish-brown rutile, and a few irregular grains of pink andalusite. Of the two types of rutile present, the rounded grains are probably original to the sediment, whilst prismatic crystals with pyramidal terminations arose from the pneumatolytic alteration of the original titaniferous content of the invaded sediments.

Dykes and Veins Cutting through the Granite.

Dyke D.1 has been given the general term "porphyry dyke" because of its variability from place to place. Dyke D.2 is also called a "porphyry dyke" because, although it has an aplitic groundmass, it is too porphyritic to be termed an aplite, though Johannsen states (16, Vol. II., p. 93), that aplites occasionally develop a porphyritic texture.

PORPHYRY DYKE D.1.

This dyke outcrops from north to south across the centre of the You Yangs granite. The strike at the southern end is N. 6° W., and at the northern end it is N. 15° W. At the north and south extremities, between P.3 and P.12, and between P.12 and the Sugarloaf, the dyke is hidden by a superficial cover of granite detritus, except for occasional pebbles along its line of strike.

On the southern flanks of the Sugarloaf, it has been displaced about 150 feet laterally by a small east-west fault.

In places along its contact with the granite, a schistosity is developed in the dyke. This is best seen in weathered blocks on the western side of the outcrop on the western flanks of P.2.

The southern portion of this dyke was first recorded by Skeats (30), and described as a hornblende porphyrite, grading into granite porphyry several hundred yards farther north. It was recorded as outcropping on the south-eastern flanks of Station Peak (now known as Flinders Peak), but, as shown on the accompanying map, its outcrop is on the south-western flanks of Grant's Hill. Coulson (5), traced the dyke north for about 2 miles through the granite, and states that its usual character is that of a felspar porphyrite, becoming a hornblende porphyrite near the diabase outcrop on the Sugarloaf.

It weathers in a different manner from the granite, and can be readily picked out in the field. The tors are generally smaller than those of the granite, and have relatively smooth faces, with angular edges. Felspar phenocrysts protrude from surfaces of granite tors, but the tendency in the dyke is for pitting to develop, as a result of the weathering out of the felspars.

The variable nature of the dyke is striking. A traverse along its strike indicates a variance from place to place in both the nature of the groundmass and the size and number of felspar phenocrysts. At the higher levels, the phenocrysts are larger and more numerous with a tendency towards a rough parallelism, and the groundmass varies from dense and bluish to coarser-grained and greyish. The main bulk of the dyke is a felspar porphyry, outcropping typically as such on P.3 and on the southern shoulder of P.12.

The local variation in the nature of the dyke is indicated by four specimens taken from an area of 2 square yards on the northern flanks of P.12, of these, two were felspar porphyry, one was hornblende porphyry, and one granite porphyry. Of twenty sections from intervals along the outcrop, three were hornblende porphyry, seven granite porphyry, and ten felspar porphyry.

Variability in the dyke is also indicated by the heavy mineral indices given in Table 4.

TABLE 4.

—	Nature of Dyke Rock.	Location.	Specific Gravity.	Index Figure.	Approximate Height.
1	Hornblende Porphyry	S. end, S. slopes P. 2	2.55	3.7	500′
2	Granite Porphyry ..	S. slopes P. 2 ..	..	13.4	600′
3	Felspar Porphyry ..	N. slopes P. 3 ..	2.59	10.3	700′
4	,, ,, ..	N. slopes P. 12 ..	2.70	11.3	750′
5	,, ,, ..	,, ,, ..	2.63	11.4	750′ to 800′
6	Granite Porphyry ..	Between P. 2 and P. 3	2.66	11.5	800′
7	Schistose Porphyry	W. slopes P. 2 ..	2.62	6.2	800′
8	Granite Porphyry ..	W.N.W. slopes P. 2	2.65	13.0	800′ to 850′
9	,, ,, ..	,, ,,	2.67	14.0	800′ to 850′
10	,, ,, ..	The Sugarloaf ..	2.63	14.3	850′
11	,, ,, ..	N.E. slopes P. 3 ..	2.69	15.4	900′

Average Specific Gravity—2.64. Average Index Figure—11.3.

From the above table, it is seen that the dyke has a higher index figure at higher points of outcrop, and that those portions referred to as granite porphyry have higher values than the felspar porphyry. The average specific gravities (2.64 and 2.65) and the average index figures (11.3 and 13.1) for the dyke and granite, are very similar. Where index numbers are higher for the dyke than average granite, it is thought that local absorption of basic xenoliths has occurred.

The heavy mineral assemblage consists of zircon, apatite, sphene, biotite, hornblende (actinolitic and uralitic), augite, chlorite, magnetite, pyrrhotite, pyrite, ilmenite, hematite, and limonite, of which biotite and hornblende are the most abundant. This assemblage resembles that of the You Yangs giant granite.

In section, phenocrysts of quartz, zoned and twinned oligoclase, orthoclase, microcline, amphibole and biotite show fritting, bending, shattering, and strain polarization. Sphene and myrmekite are not common, augite has been altered to fibres of actinolite. Small idiomorphic felspars with cloudy cores are often jacketed with a rim of clear oligoclase, and are characteristic of the dyke. The cloudiness is due to minute inclusions of limonitized iron ores, probably produced by the reheating of basic felspars derived from incorporated xenoliths (19). The groundmass is fine-grained to microcrystalline, but may be coarser in texture where patches of micrographic intergrowths occur. Schistose portions of the dyke show flow banding, produced by the streaming of groundmass constituents around phenocrysts.

Granite fragments included in the dyke show embayment and shattering of quartz and felspar crystals, and contortion of biotite flakes. Similar structures occur in the granite at the walls of the dyke, where a microgranular groundmass has been produced similar to that in parts of the dyke.

Xenoliths in Porphyry Dyke D.1. These comprise (i) small fragments of granite, (ii) xenocrysts of quartz, oligoclase, orthoclase-perthite, clots of biotite, actinolite and diopside, and aggregates of felspar containing inclusions of biotite, actinolite and zircon, all of which have been derived from the granite, (iii) occasional xenoliths of foreign rocks similar to those of sedimentary and doubtful origin in the granite. The xenoliths of class (iii) are not numerous, and are best seen where the dyke outcrops on the eastern flanks and southern shoulder of P.12. One example contains areas of microcline in a hybrid zone thought to have been developed in the granite prior to its incorporation in the invading dyke.

There is a remarkable similarity in hand specimens of certain portions of the dyke, and certain of the more granitized xenoliths with porphyritic textures which occur in the giant granite. They contain clots of ferromagnesian minerals, and it is thought that where the index figure for dyke exceeds that for average granite, the excess ferromagnesian content has come either from further local assimilation of basic xenoliths already partially granitized by the granite, and/or directly from the roof rock into which the dyke stoped its way.

Rapid chilling occurred at parts of the contact with the granite, and the oncoming less viscous magma of the dyke exerted a drag on the chilled dyke-wall material, producing schistosity. The schistose portions should supply a closer approximation to the original composition of the dyke magma than the interior parts. The index number of the schistose portions is lower than those of the bulk of the dyke (see Table 4), indicating an initial acid composition.

It has been stated that reaction products sink in vein granite which is undergoing basification by assimilation of gabbroic xenoliths, and that porphyritic felspars become increasingly prominent the more foreign material has been assimilated, the ferromagnesian content showing no steady downward increase (34, p. 197). Similar phenomena occur in porphyry dyke D.1 at the You Yangs, except that sinking of reaction products is not indicated by the index figures, higher values being obtained for the higher levels of the dyke. The textural variability, prominence of porphyritic felspars and increase of index figure with height, therefore lead to the conclusion that the dyke was intruded as an acid magma which advanced along a crack in the granite. After stoping and assimilating some of the granite and its inclusions, it penetrated the roof rock, and consolidated before even dispersal throughout its mass occurred, of the contamination minerals which it had obtained.

Porphyry Dyke D.2.

On the south-western flanks of P.2, there occurs a 20-ft. wide dyke which is leucocratic and porphyritic. It is labelled on the map as D.2, and has a strike of N. 11° E. It is older than porphyry dyke D.1, which appears to cut across it, but no actual contacts are displayed. Professor Skeats refers to this occurrence as an acid dyke (30). The same dyke outcrops again on P.8, where it is reduced in width to 10 feet, and strikes N. 18° E. Numerous veins and dykes of aplite and a few veins of felspar with medial strands of quartz, are developed close to this dyke, and in a few instances may be observed as definite offshoots from it. On P.2, the dyke bifurcates, the main channel continuing along the general line of strike, whilst a narrower channel strikes almost due north.

In section, the dyke consists of phenocrysts of quartz and oligoclase set in a saccharoidal groundmass comprised of quartz and microcline sometimes intergrown, orthoclase, oligoclase, biotite, apatite and zircon; secondary limonite is present along cracks and mineral junctions.

The index figure is 4.0, being about the same as that for aplite (4.1). The sp. gr. is 2.60, and the assemblage of heavy minerals consists mainly of biotite, occasional zoned zircons with inclusions, rare magnetite and pyrrhotite, and very rare hornblende.

Aplite.

Numerous dykes and veins of aplite cut the You Yangs granite in all directions, and are concentrated in the south-eastern portion of the area. They are usually cream-coloured, but may be pink from secondary iron staining. The greatest development is on P.1, P.2, and P.8, i.e., in the neighbourhood of Dyke D.2. A few narrow veins occur at the Sugarloaf, Big Rock, and on the southern flanks of Flinders Peak.

On the south-eastern slopes of P.6 is an irregular intrusion of aplite (Plate XI., Fig. 2), which is rather coarser in grain than the dykes and veins. It contains xenoliths of granite, and has created a local planar parallelism in the minerals of the granite for a distance of 2 feet from the contacts.

There is no apparent relationship between the injection of the aplite and jointing in the granite, for in most cases, the aplites cut right across the joint planes.

The width of dykes and veins varies from 1 inch to 10 feet, and they often contain felspar secretions and strands of quartz. Their dip varies from 13° to vertical, and in rare cases they are horizontal.

In thin section, the aplites are uneven in grain size, but usually have a saccharoidal texture, the grains being sutured and intimately interlocked. They consist of quartz, microcline, partly sericitized orthoclase, rare oligoclase, occasional plates and sheaves of muscovite, biotite, and secondary limonite outlining some of the grains. Micrographic intergrowths occur between quartz and microcline, and quartz and orthoclase. Myrmekite is rare. The coarser-grained aplites are inclined to be porphyritic, but do not develop phenocrysts as prominently as in porphyry dyke D.2.

The sp. gr. is 2.59, and the index figure 4.1, and in the heavy mineral assemblage, biotite is the most important, accompanied by chlorite, magnetite, hematite, limonite, zircon of the giant granite type, and rare hornblende.

Pegmatite.

Occasional lenses and strands within aplite, and veins in granite have pegmatitic affinities. The strands may be more or less central, or present as coarser-grained edges to aplite veins (9), the former occurrences being the more common. The pegmatite is much more restricted than the aplites, and like them confined to the south-eastern portion of the area.

Graphic intergrowths, white to cream-coloured, twinned felspars, and a few small books and shreds of biotite are visible in the hand specimen. Under the microscope, they consist of quartz, microcline-microperthite graphically intergrown with quartz, orthoclase-perthite with irregular intergrowths of quartz, radial intergrowths of quartz and microcline, and granophyric intergrowths of the same minerals. Oligoclase and myrmekite are uncommon, and the microcline crystals sometimes show mortar structure. Biotite and muscovite are occasionally present, and limonite occurs along cracks and cleavages.

Coarse-grained quartz-felspar veins, 3 inches wide, occur on the southern flanks of P.1 and at Big Rock, and they grade imperceptibly into the granite. They taper, seldom possess parallel walls, and usually show graphic intergrowths.

Quartz Veins.

Quartz veins are scarce. A 4-in. vein occurs on the north-eastern slopes of P.8, a few narrow veins penetrate both the granite and aplite, and are probably associated with the last phases of injection of porphyry dyke D.2. On the western flanks of P.2 a vertical 1-ft. dyke of reef quartz, striking E. 40° N., has been unsuccessfully worked for gold. It penetrates the granite and porphyry dyke D.1, and has been trenched where it crosses the dyke. Contacts with the dyke are wavy but well defined. This quartz dyke consists of a sutured, interlocking aggregate of quartz grains of variable size, with occasional thin films of reddish-brown iron oxide outlining them.

The veins and dykes of aplite, pegmatite, and quartz-felspar are derived from the rest magma of the granite, and according to Johannsen (16, vol. 11, p. 92), would be intruded whilst the granite magma was consolidating or shortly after while it was still hot, and he states that the aplites are similar in composition to the parent rock, except that they represent a leucocratic differentiation phase. The You Yangs aplites would therefore be termed Granite-Aplites (16).

The patches and strands of coarse quartz and felspar crystals are probably attributable to some kind of filter-press action under stress, whereby the fluid residuum of low consolidation temperature was expressed at a late stage in the consolidation of the larger mass of the granite (3, p. 222). Where aplites, and pegmatitic patches and strands are intermingled, the residuum was a more fluid pegmatite magma which was injected before the aplite, so that pegmatite which had ceased to crystallize in the passages which it occupied, was pushed aside or surrounded by the later aplitic magma, the aplite filling in any remaining cavities and passages in which no pegmatite had crystallized. As a result of these processes (quoted from Anderson in Johannsen (16, vol. 1, p. 97), the aplite would form a border zone in some cases and occur as central strands in others.

Monchiquite and Nepheline Monchiquite.

Two dykes and a small plug of monchiquite occur at the You Yangs, and are marked on the map as D.3. One dyke is a nepheline monchiquite. They intrude the granite, and may be associated with the late Tertiary (Newer Basaltic) igneous activity (31). Their trend is controlled by the north-western-south-eastern major joints of the granite.

The small plug, which is very weathered, is 20 feet x 10 feet in area, and occurs on the northern flanks of P. 11. One of the dykes occurs on the north-north-eastern and northern slopes of Flinders Peak, and is much fresher than the plug. It is 8 feet to 9 feet wide, and has been traced for 400 yards. The strike is W. 40° N. The dyke is not exposed all along its outcrop, but disappears from view under the recent sands and gravels of a small tributary to Branding Yard Gully between the northern end of Flinders Peak and P.5, and reappears on the saddle between P.4 and P.5. It has not been found further north-west than this saddle, nor further south-east than the 400-ft. contour above Branding Yard Gully, on the eastern side of Flinders Peak. The other dyke, which is nepheline-bearing, outcrops for a distance of about 30 yards on the north-eastern slopes of P.6, and is situated south-west of Quarry 1. It is 10 feet wide.

The outcrops of monchiquite are represented by small boulders of dark brown colour, intermingled with granitic detritus. The outcrop on Flinders Peak has an amygdaloidal appearance, its sp. gr. is 2.95, and heavy mineral index 69.2. Phenocrysts of pale yellowish-green augite are abundant in the fresher samples.

The nepheline monchiquite on P.6 tends to be lamprophyric, containing occasional large plates of biotite 0.5 cms. across, and crystals of black augite 1.75 cms. long. It also contains segregations of biotite and augite, and a few xenoliths of granite.

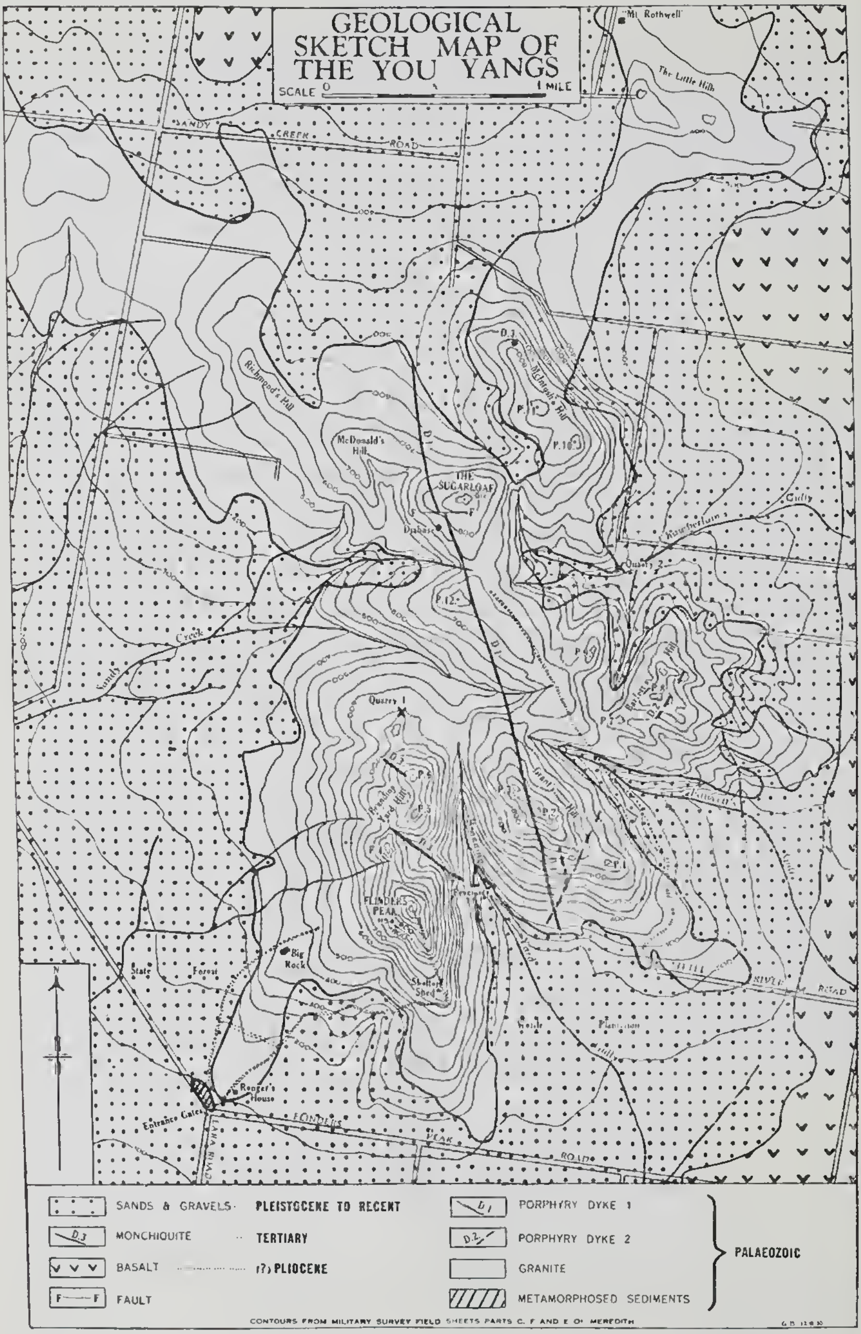
In section, the monchiquite is porphyritic to glomeroporphyritic. Augite phenocrysts are abundant as large idiomorphic crystals, smoky-grey in colour, and carrying strings of small bubble-like inclusions. Smaller crystals of augite, with occasional interpenetration and multiple twins, are green or pale violet in colour, and pleochroic. Some of the pale violet (titanaugite) crystals include sharply differentiated cores, often green, of resorbed aegerine-augite, similar to those described by Edwards from Victorian Tertiary lavas (10). Augite is also abundantly developed in the groundmass as very small granular, and idiomorphic, pale violet to colourless crystals.

Olivine is not common, but shows occasional good crystal outlines, (100) cleavages, and irregular cracks along which serpentinization and iddingsitization have occurred. It is mainly present as grains of irregular shape, and is at times surrounded by a zone of augite.

Biotite is present as large plates free from inclusions, and also as small brown crystals in the groundmass. The amygdales contain calcite and occasional analcite. Ilmenite occurs throughout the rock as innumerable grains, and is partly altered to secondary iron oxide. It may rim serpentinized olivine, or occur as granular cores in augite. Picotite is rare, shows two good cleavages, black borders, and is greenish-brown in colour.

The groundmass in the P.11 and Flinders Peak occurrences consists of a brown isotropic glass containing crystallites of augite. In the nepheline monchiquite, glass is rare, while idiomorphic and interstitial areas of nepheline are abundantly developed.

The effect of the inclusion of xenoliths of granite in the nepheline monchiquite of P.6 has been the abundant development of microlites of augite at contacts, and an introduction of the groundmass of the dyke along cracks in the xenoliths. This has attacked and decomposed most of the biotite with the formation of a brown glass. Calcite and nepheline occur in one of the granite inclusions near the junction with the dyke rock. In these xenoliths of granite, microcline is only sparsely represented, so that such inclusions may represent a non-porphyritic, deep-seated phase of the granite mass.


GEOLOGICAL SKETCH MAP OF THE YOU YANGS
SCALE 0 1 MILE
Mt. Rothwell
The Little Hill
SANDY CREEK ROAD
Richmond's Hill
McDonald's Hill
THE SUGARLOAF
Diabase
McIntyre's Hill
Quarry 2
Quarry 1
Sandy Creek
FLINDERS PEAK
Big Rock
State Forest
Ranger's House
Entrance Gates
FLINDERS PEAK ROAD
RIVER ROAD
SANDS & GRAVELS PLEISTOCENE TO RECENT
MONCHIQUITE TERTIARY
BASALT (?) PLIOCENE
FAULT
PORPHYRY DYKE 1
PORPHYRY DYKE 2
GRANITE
METAMORPHOSED SEDIMENTS
PALAEOZOIC
CONTOURS FROM MILITARY SURVEY FIELD SHEETS PARTS C, F AND E OF MEREDITH

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Explanation of Plate XI.

Fig. 1.—Portion of face of Quarry 1. a—bands of coarse-grained granite, b—basic schlieren (biotite bands), c—joint face, d—biotite clots, e—giant granite, f—non-porphyritic granite, g—curved horizontal joint plane. The structure resembles that of a drag-fold with minor puckers. The size of the face shown is about 15 ft. by 12 ft.

Fig. 2.—Irregular intrusion of aplite showing jointing.

1

2

You Yangs Granite.

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